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No. **17601**

Date **14 JUN 1934**

Received documents purporting to be the Application and Provisional Specification of L. Szilard

which have been numbered and dated as above,

M. F. LINDLEY,

Comptroller-General.

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Transmutation of the elements by different ~~particles~~ particles

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PROVISIONAL SPECIFICATION.
(To be furnished in Duplicate.)

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(a) Here insert title verbally agreeing with that in the application form.

(a) Transmutation of chem. elements by efficient particles.

(b) Here insert (*in full*) name, address and nationality of applicant or applicants as in application form.

(b) I (or We) ....

do hereby declare the nature of this invention to be as follows :—

(c) Here begin description of the nature of the invention. The continuation of the specification should be upon wide-ruled paper of the same size as this form, on one side only, with a margin of one inch and a half on the left-hand part of the paper. The specification and the duplicate thereof must be signed at the end and dated (thus): "Dated the day of 19 ."

(c) ....

(*Y8385) Wt 15367/3534 60,000(4) 11/32 H & Sp Gp 102

withdrawn whole spec. —

Korn.

Transmutation of chemical elements by efficient particles.

The invention conserns the production of power, the storage of power and the production of radioactive bodies through processes in which neutrons of simple or multiple mass, or negative nuclei are generated. The following symbols will be used for negative nuclei: H(1) for the negative proton, H(2) for the negative diplon; similarly H(3), He(3), He(4) ... for negative nuclei the mass and charge of which corresponds to the positive nuclei H(3), He(3), He(4). Elements the mass number of which is larger than twice the atomic number will be called "overloaded". Neutrons of simple or multiple mass are also considered to be "overloaded" elements. Negative nuclei may be generated by shooting "overloaded" atoms for instance on "overloaded" elements; in order to determine which element yields negative nuclei when bombarded by "overloaded" particles one has to investigate each element by means of a Wilson cloud chamber. If a magnetic field is applied to the said chamber the curvature of the tracks generated by the bombarded element will show if negative nuclei are present in the radiation of the element under investigation. If matter is radiated by negative nuclei those can be captured by the positive nuclei without necessarily falling at once into the positive nucleus, i.e. the binding energy can possibly be small at least for a certain period of time after the capture. Bombardment of Hydrogen, H(1), Diplogen, H(2), Triplogen, H(3) by negative protons may lead to the generation of neutrons in which the positive and negative nucleus is possibly only loosely bound for some time after the generation.

For instance the binding energy between a positive and negative proton may at first be between ten and twenty thousand volts. Neutrons in which the nuclei are loosely bound will be called subsequently pseudo-neutrons and the symbols $\overline{n}(2)$, $\overline{n}(3)$ and $\overline{n}(4)$ to distinguish them from the real neutrons of the same mass number for which we shall write n(2), n(3) and n(4). Such pseudo-neutrons would suffer energy losses if they travel through matter at a given speed which are large as compared to the energy losses for real neutrons at the same speed. While positive nuclei do not cause transmutation if they have reached the end of their range this may be the case for negative protons and other negative nuclei and for such nuclei which contain instably (loosely) bound negative nuclei, for instance pseudo-neutrons. They may be, therefore, equally efficient as real neutrons, the range of which is very large and may therefore be used in the processes and in the apparatus which is subject to this invention. We shall call them "efficient particles" under which name we understand neutrons, negative nuclei and pseudo-nuclei (pseudo-nuclei are pseudo-neutrons, or positive nuclei which contain loosely bound negative nuclei and therefore can cause transmutation even when at the very end of their range).

The preceding part of the description served only to define the scope of the word "efficient particle". The following chapter deals with the invention itself which concern methods and apparatus for the production of power, for the storage of power and for the production of radioactive bodies by means of chain reactions the links of the chain being "efficient particles".

1. We choose an element "C" for our process so that its mass (packing fraction) should be sufficiently

high to allow that it should disintegrate into parts under liberation of energy in accordance with the law of conservation of energy. We call such an element, if it does not disintegrate appreciably spontaneously, "metastable", in order to indicate that the disintegration is inhibited. We shall call the element "very metastable" if it is "metastable" and if its disintegration under liberation of energy would be possible without making the emission of positive or negative electrons necessary in the primary process. We consider now an element "C" which is "metastable" and which disintegrates when bombarded by an "efficient particle" "Z" in a certain percentage of collisions under liberation of energy accordingl to the equation

1a. "C" + "Z" = "D" + "Z" + Energy

i.e. the element "C" will under the influence of the "Z" radiation be able to transmute, the inhibition which prevented its transmutation being lifted in the collision.

~~in spite of sufficient energy being available for the transmutation (as revealed by the large mass of the atom) is lifted and the element "C" transmutes into "D".~~ The symbol "D" ~~comprises~~ does not necessarily indicate one element but may indicate two or more elements, parts, into which the element "C" may disintegrate.

1b. "C" + "Z" = "E" + "Z" + "Z"

i.e. under the influence of the "Z" radiation the element "C" transmutes into "E" and "Z". If energy is liberated in the reaction 1b, we can consider 1b as a special case of 1a in which "D" = "E" + "Z".

We shall call elements which are capable of reaction 1a "metastable" or more precisely "efficient metastable elements". We call them metastable in order to indicate that their energy is sufficient to allow for spontaneous disintegration into parts, that spontaneous disintegration is inhibited, and that inhibition can be lifted by bombardment (by radiation with certain particles). We shall call them "efficient metastable ~~particles~~ elements in order to indicate that ~~in disintegrating~~ the inhibition can be lifted by "efficient particles". Elements which satisfy 1b, leading to a liberation of energy in reaction 1b, we shall call "metastable multiplicators" to indicate that in disintegrating ~~thereby~~ they yield efficient particles. Among the light elements those which have an odd atomic number and an even mass number or which have an even atomic number and an odd mass number have unusually large masses (packing fractions) and tends to be metastable. By measuring the mass of these elements it is possible

to determine which is actually metastable and which is not. An example for a metastable element which is at the same time an "efficient metastable element" and an "metastable multiplicator" is Beryllium. Beryllium if bombarded by neutrons gives reaction 1: L.)

$Be(9) + n(1) = "D" + n(1) + Energy$

Where "D" breaks up;

a. $"D" = He(4) + He(5)$

b. $"D" = He(4) + He(4) + n(1)$

As the mean free path for an efficient collision in Beryllium is for neutrons of the order of magnitude of 10 cen. to 100 cen. a chain reaction can only develop if a large bulk of Beryllium (the linear dimensions of which may even exceed twenty metres) is exposed to radiation of neutrons or to a radiation which generates neutrons in the Beryllium. One can use for instance, a high voltage tube which generates fast diplons and generate neutrons by exposing Diplogen, Lithium or Beryllium to the Diplons in a transmutation chamber. This transmutation chamber can be surrounded by a Beryllium layer of several metres thickness, so that under the influence of the neutron radiation emerging from the said transmutation chamber, a chain reaction should set in in the Beryllium, yielding to an energy liberation in the Beryllium comparable to the energy input or exceeding it many times or else that the chain reaction should lead to a liberation of neutrons in the Beryllium exceeding many times the initial neutron radiation of the transmutation chamber. By utilising the energy liberated in the Beryllium or the energy which can be liberated by abborbing in a substance "P" the neutrons which have been liberated in the Beryllium (for instance by absorbing them in Lithium) boilers or other heating elements of caloric machines can be operated and power can be produced.

L.) Beryllium is very metastable

By exposing an element "G"(which will transmute into a radioactive body when bombarded by neutrons) to the radiation emerging from the Beryllium (the thickness of the "G" material being of the order of magnitude 10 to 100 cen.) energy can be stored with a sufficiently good efficiency even in those cases where the initial transmutation in the said transmutation chamber is extremely inefficient.

A chain in which the links are formed by neutrons is interrupted if the neutron gets transformed in a collision into a proton the latter being not an "efficient particle". Such interruption are however very seldom in Beryllium, Beryllium being an"overloaded" element"i.e. an element the mass number of which is larger than twice the atomic number. Neutrons colliding with Beryllium atoms may be transformed into negative protons but these being "efficient particles" need not interrupt the chain.

An Essential features of the method for the production of power, the storage of power and the production of radioactive bodies described in this paragraph (1.) is the combination of an "efficient metastable element" for instance Beryllium, with means of generating a radiation of"Efficient particles";in the case of Beryllium for instance a means for accelerating diplogen or other ions by electrical devices so as to generate a initial neutron radiation acting on the Beryllium. Another essential feature is the proper choice of the arrangement and bulk of the metastable element so as to get chains of sufficient length. Another essential feature is to utilise the heat liberated the metastable element for heating the boiler or other parts of a caloric machine. Another essential feature is

The exposure of a thick sheet of material "G" to the "efficient particles" emerging from the metastable multiplicator which leads to storage of energy in form of radioactive bodies.

If we have an "efficient metastable element which is not a multiplicator we can still use it by mixing it with an element/"L" which is not metastable but which is a multiplicator,(i.e. in the reaction

$$\text{Energy} + \text{"L"} + \text{"Z"} \xrightarrow{} \text{"M"} + \text{"Z"} + \text{"Z"}$$

there is no liberation but absorption of energy).

Figure 1. shows a high voltage positive ray tube which is similar to a tube described by Cockroft and Walton and which can be used in combination with means described in figure 3 and 4 to furnish the initial radiation necessary to the chain reaction in the "efficient metastable element". ~~Kixxxx~~ 11 is the anode of the positive ray tube (which is on top of the high voltage tube) 15 is the cathode.Diplogen ~~ix~~ or Helium is admitted through the tube 13 and pumped away through 14. The positive ions are accelerated and enter the transmutation chamber 20. One can in this way produce a neutron radiation by bombarding Diplogen with Diplogen or Beryllium with Diplogen or Lithium with Diplogen or Beryllium with Helium etc. The radiation emerging from the chamber 20 will be called "initial radiation". The tube can be operated by an impluse generator shown in figure 3 (parts 1 to 25).

Figure 2 shows another method to create the initial radiation. Chamber 44 contains Diplogen which is treated by an electrical discharge in which energy that has been stored by electrical or ~~mechanical~~ magnetical means is suddenly released.~~xxxxxxtoxproducexaxhighxtemperaturexinxthexDiplogen~~ In figure 2 a high voltage source is connected through the chokes 53 and 54 to the dondensor 52 which is suddenly discharged through the spark gap 51 which is connected to the cathode 42. The cathode rays are concentrated on the space 44 which contains Diplogen or mixtures of Diplogen and Triplogen. The operation of this device leads to neutron radiation which can be used as initial radiation in combination with the matter described in figure 4. The impülse generator described in fägure 3 can be used to operate the device described in figure 2.

Figure 4 shows a device consisting of a device 60 adapted to produce the initial radiation for instance as described in Figube 1 or Figure 2, 61 being the area emitting the initial neutrons. This area is surrounded by a large bulk of an efficient metastable multiplicator such as for instance Beryllim or a mixture of an efficient metastable element which need not be a multiplicator, and a multiplicator which need not be a metastable element. The linear dimensions of the material "C" surrounding 61 can be as large as needed to get sufficiently long chains. "C" is surrounded by a layer of "G" of the order of about one metre of thickness, the element to be used for "G" so chosen as to transmute into a radioactive element of sufficiently large half period under the influence of the radiation emerging from "C". The material 62 surrounding "G" is a heat insulator. There is a pipe system indicated by 63 operatäd by a pump 64 through which water or mercury is circulated so as to cool the material "C" and "G" and the heated liquid is used in a caloric machine. The boiler of a steam turbine or other caloric machines can also be, if necessary, directly immersed into the material "C".

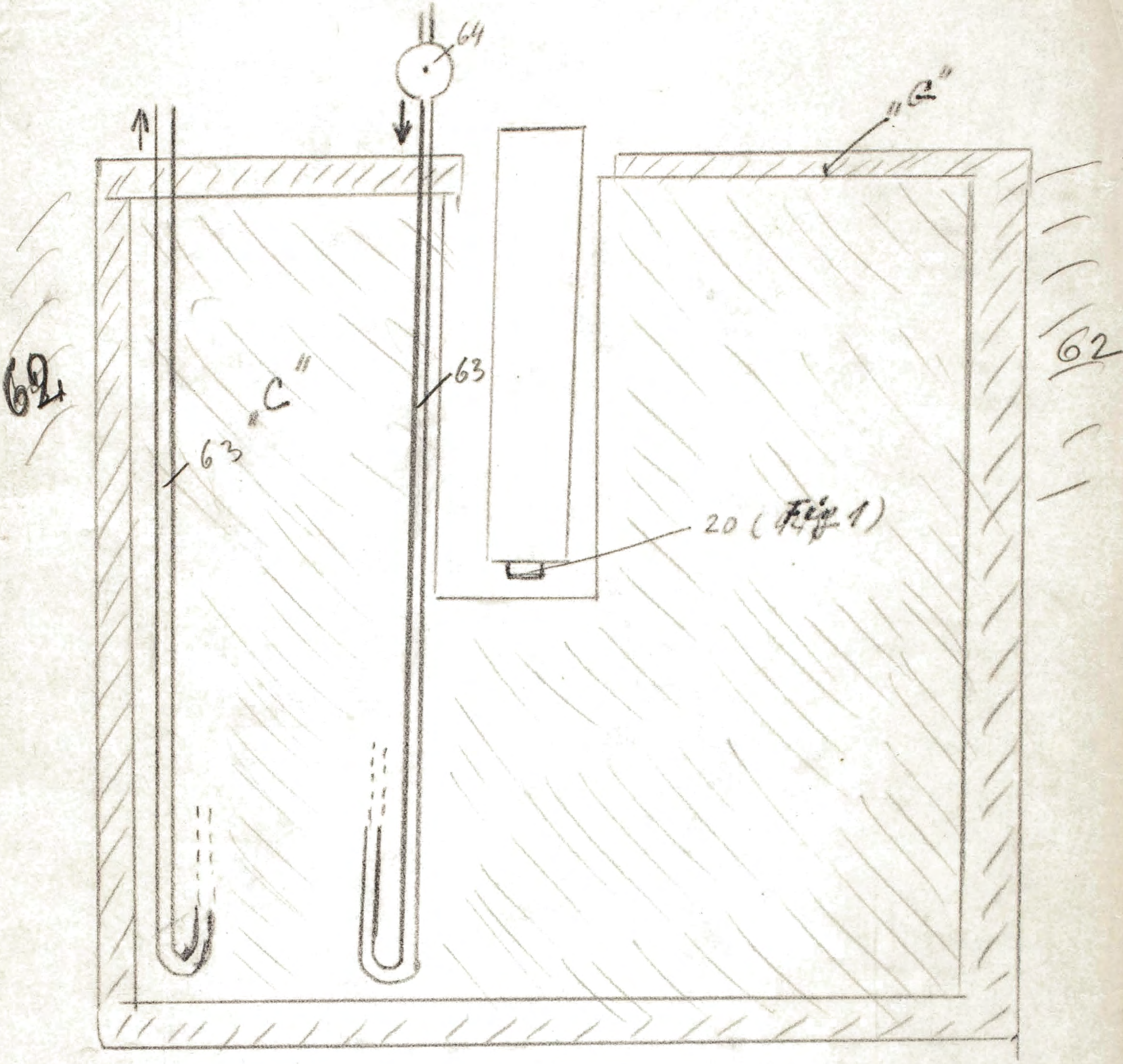

Fig 4.

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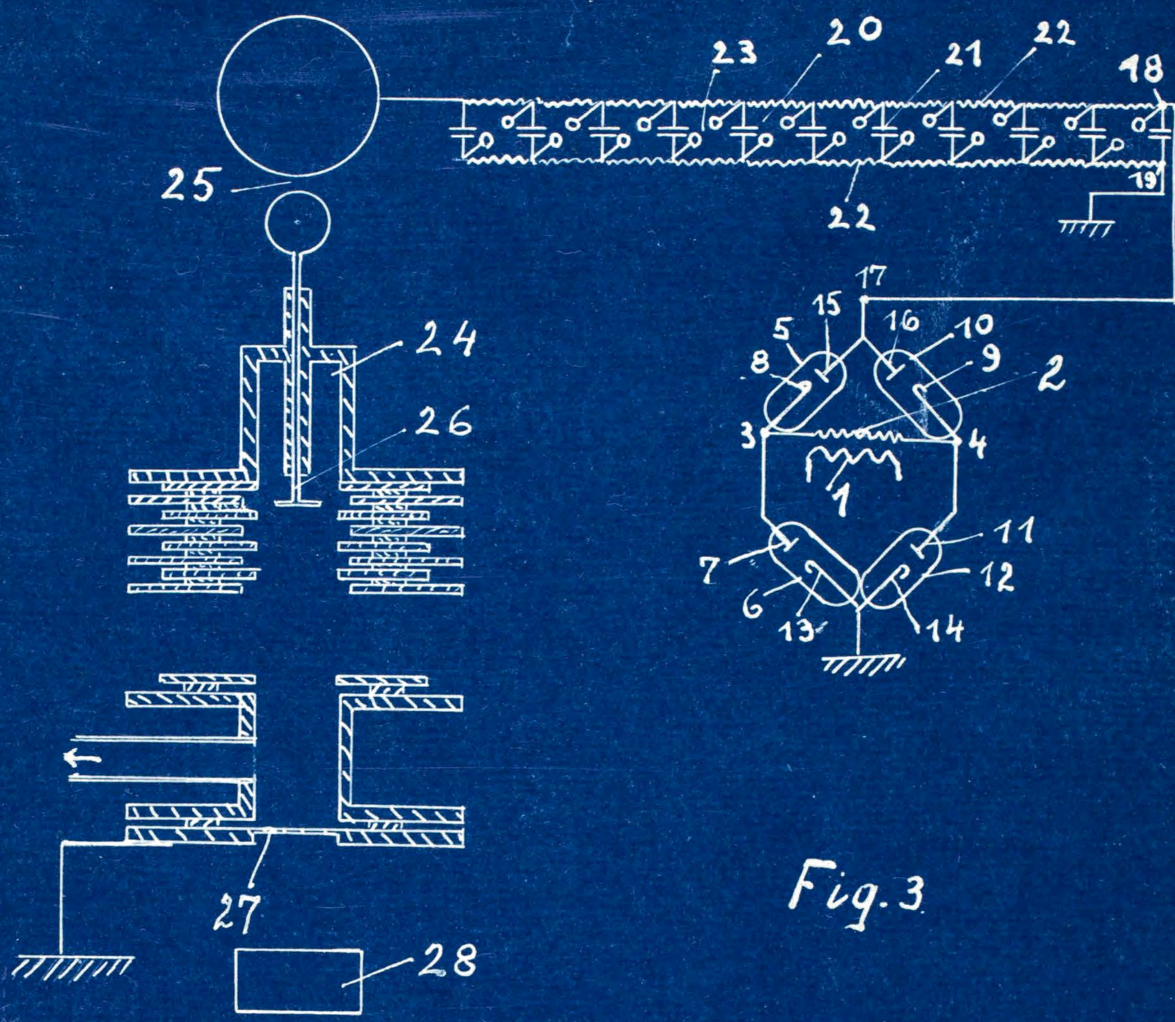

Fig. 3

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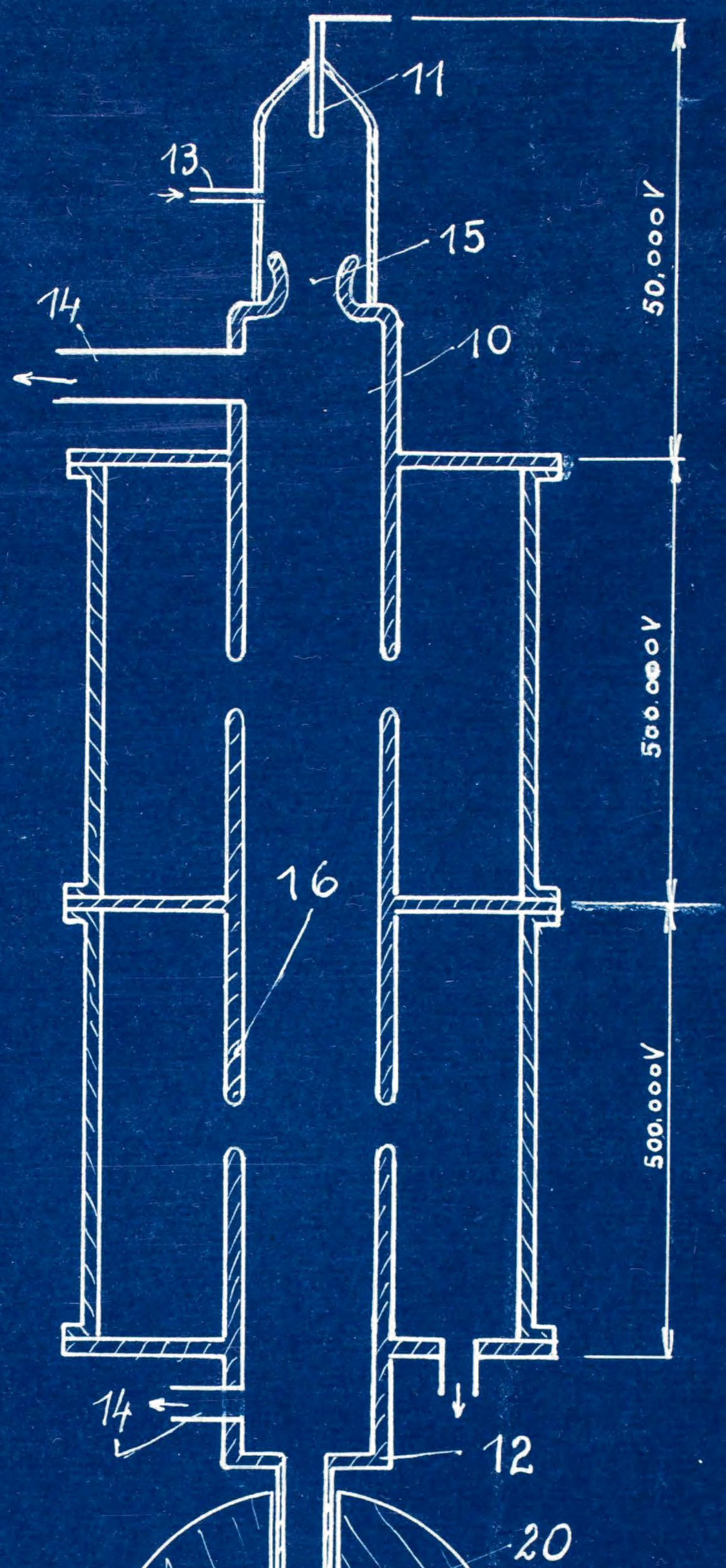

Fig. 1.

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